



Winter Spinach Production in High-Tunnels, 2014-2016

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Background & Objectives

Spinach is a suitable crop for winter production in New Hampshire due to its ability to continue producing saleable leaves at very low-temperatures. Fall transplants into high tunnels can result in winter-long harvests and significant spring yields, providing an avenue for growers to meet strong consumer demand for local greens during the “off” season.

With the goal of providing recommendations for winter spinach production in high tunnels, we performed experiments over two winter seasons using fall-planted spinach seedlings. We focused primarily on three spinach varieties: Regiment, Space, and Tyee, and planted these varieties at six different dates throughout the fall, ranging from 20 September to 9 November. At our third planting date (9 Oct) we added five varieties to the study: Carmel, Corvair, Gazelle, Emperor and Renegade. The study objectives were to:

1. Determine **yield potential** of Regiment, Space, and Tyee for each fall transplant date and identify best transplant dates
2. Evaluate all eight varieties for their **suitability for winter production**
3. Assess the leaf **sugar content** among varieties throughout the winter season
4. Identify discernable growth and leaf **characteristics** among varieties that may assist growers in choosing those best suited to their market/objectives

Methods

Trials were conducted at UNH’s Woodman Horticultural Research Farm, at the Agricultural Experiment Station in Durham, NH (zone 5B) over two winter seasons: 2014-15 and 2015-16. The same six planting dates were utilized in both years.

<i>Planting Date</i>	<i>Seeding Date</i>	<i>Transplant Date</i>	<i>Varieties Used</i>
#1	29 August	20 September	Regiment, Space, Tyee
#2	8 September	30 September	Regiment, Space, Tyee
#3	18 September	9 October	Regiment, Space, Tyee, Carmel, Corvair, Gazelle, Emperor, Renegade
#4	29 September	19 October	Regiment, Space, Tyee
#5	9 October	30 October	Regiment, Space, Tyee
#6	19 October	9 November	Regiment, Space, Tyee

Seeds were sourced from:

High Mowing Organic Seeds: Regiment & Corvair

Johnny’s Selected Seeds: Space, Tyee, Carmel, Gazelle, Emperor & Renegade



Unheated high tunnels were used in both years. During the 2014-15 season, we used a 60' x 30' stationary high tunnel (Ledgewood Farms, Moultonborough, NH). The tunnel was covered with a single layer of 6mil, 4-year UV treated polyethylene plastic with polycarbonate end walls and was equipped with two louver vents and exhaust fans set to vent at 70°F. Roll-up sides were manually adjusted for additional ventilation and were permanently lowered for the winter on October 19, 2014.

In 2015-16, a 48' x 30' moveable Rolling Thunder high tunnel (Rimol Greenhouse Systems Inc., Hooksett, NH) was used. The tunnel was covered in an inflated double layer of 6 mil, 4-year plastic and also had polycarbonate end walls. Gable shutters vented at 60°F, and automated roll-up sides maintained an inside temperature below 70°F. Ventilation through the automatic roll-up sides was disabled for the winter on December 13, 2015.

Cultural Details: Soil within high tunnels was tested and amended (pre-plant incorporated) based on recommendations for spinach. In both years, we constructed four long beds ranging from 4-5' wide and 40-50' long, depending on high tunnel used, with enough space between rows to accommodate harvesting.

Germination & Transplant: Seeds were started in 128-cell trays of Pro-Mix BX soilless media. In 2015, very high temperatures in late August inhibited germination of the first seeding. To ensure adequate plant quantities for the study, all later plantings were germinated in a growth chamber (Percival Scientific, Perry, IA) set at 60°F for 7 days. Seedlings were transplanted at 3 weeks of age in rows 8" apart with an in-row spacing of 5". We used a randomized complete block design with four replicates of each variety/planting date combination, 24 plants per rep.

Management

Irrigation: Seedlings were irrigated following transplant and as needed using a combination of drip tape (2014-15) and overhead irrigation (2015-16). It was necessary to provide water during the winter months, especially December-February in 2015-16.



Raised beds prior to planting,
September 2015



Seedlings ready for transplant,
October 2015



Row cover over spinach,
December 2015

Row cover: When temperatures began to consistently dip below freezing, an Agribon+ AG-19, 0.55 oz/yd² row cover was suspended approximately 3' above plants for additional insulation. The row cover was applied 6 November (2014-15) and 14 December (2015-16). For easy removal, we laid the cover across four cables that were installed to run the length of the tunnel. It was kept taut by clipping the cover to the outer two cables with clothespins so it did not make direct contact with plants. During the winter, the cover was only removed for the purpose of harvesting and irrigation, and in both years was permanently removed in March when daytime temperatures began reaching 50°F.

Pest management: In 2015-16, *Bacillus thuringiensis* (Dipel DF) was applied twice to control cutworm (6 November and 10 December). We controlled a high aphid population in February 2016 by three releases of ladybeetles (*Hippodamia convergens*; A-1 Unique Insect Control, Citrus Heights, CA).

Harvest

In year one, harvesting began 30 October 2014 and concluded on 15 April 2015, when plants bolted. In year two, harvesting began 19 October 2015 and ended 8 April 2016. Carmel was the only variety to bolt by the time harvesting was terminated in 2016. We began harvesting when leaves reached marketable size, defined as 4-6" from petiole base to the tip of the leaf apex. At each harvest, all leaves of marketable size were removed by pinching the base of the petiole. Harvests were conducted approximately every two weeks from October through April, with the exception of January and February when we harvested once per month due to the slower pace of plant growth.



Ladybeetles hunt for aphids,
April 2016



Talia Levy harvests on 18 December 2015.



RESULTS: Planting Date

Days-to-harvest: The number of days from transplant to first harvest increased steadily with each later transplant date. With the exception of the first transplant date in 2015-16 (which was plagued by poor germination), days to harvest was highly dictated by transplant date. This is shown in **Figure 1**. This period was as short as 19 days (transplant #2 in 2015) and as long as 130 days (transplant #6 in 2014). We attribute the variation between years to the difference in temperature between winter seasons, as shown in **Figure 2**.

Yield: Planting date also impacted the total yield from first harvest through last harvest; with earlier transplant dates producing significantly a higher total yield than later transplant dates. **Figure 3** shows the difference in yield by transplant date, and year. During the first year of the study (2014-15), the first three dates had similar total yields, though the second was technically lower than the first. In the second year of the study (2015-16), the first two transplant dates did not differ from one another in total yield at all. However, in both years we observed yields tended to decrease steadily with each consecutive planting date.

The 2015-16 season produced much higher yields than 2014-15, most likely due to a very mild winter.

Figure 3. Average total yield for each transplant date. Values are an average of Regiment, Space and Tyee. Values with the same letter are not significantly different from one another, *within each year.

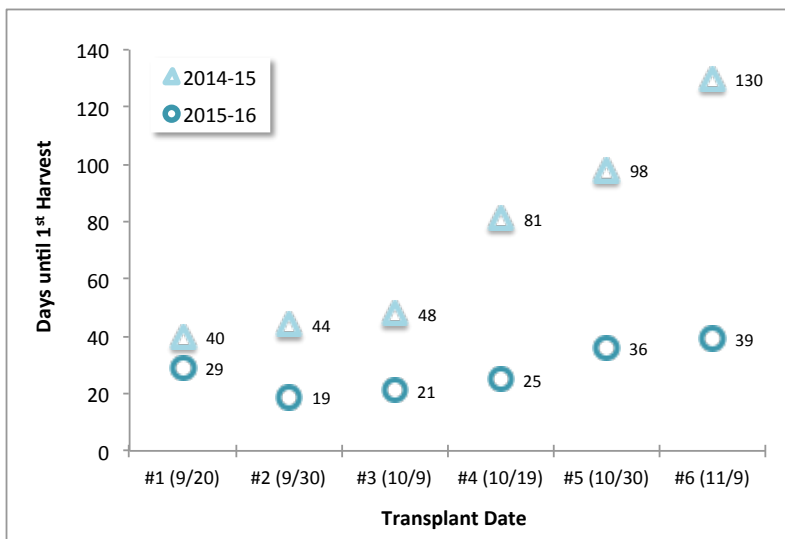


Figure 1. Days to harvest for each of the six transplant dates during 2014-15 and 2015-16.

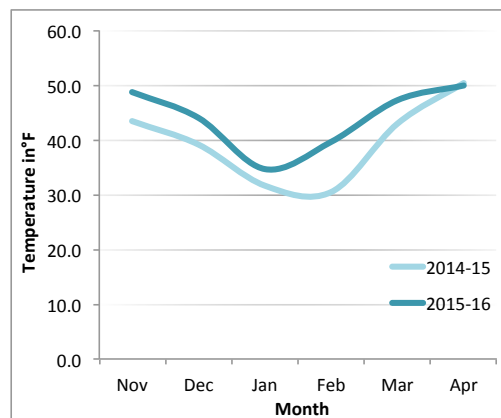
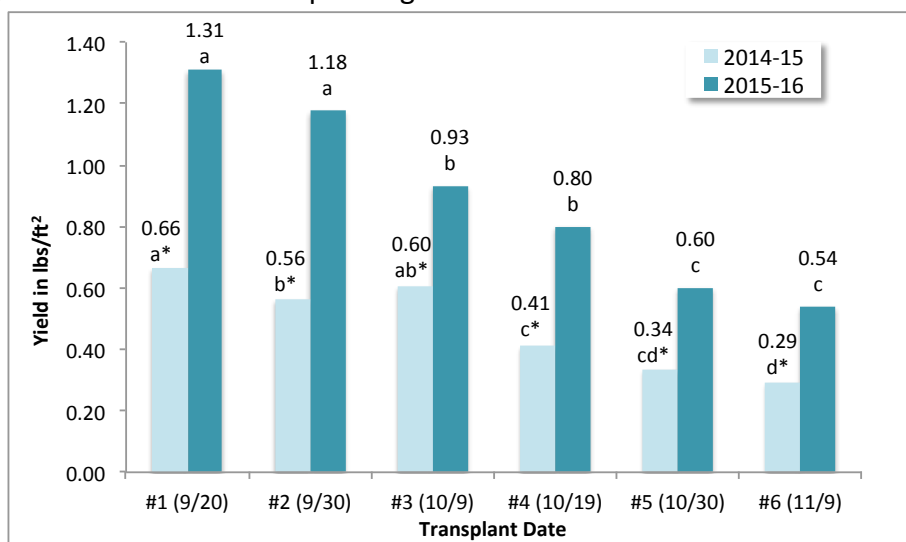


Figure 2. Average monthly temperatures.





During the second year of our study, the first transplant date (20 Sept) produced nearly three times the cumulative yield than the latest transplant date (9 Nov), and in the first year of the study, it was double. This variation in total yield among transplant dates demonstrates the importance of keeping the target market in mind when choosing a transplant date.

If fall/early winter production is the objective, our study suggests that earlier transplant dates will result in the highest autumn/early winter yields. As shown in **Figure 4**, the 20 Sept and 30 Sept transplant dates produced significantly more by January than any of the later dates. It is also clear that transplanting later than mid-October results in little production prior to and during the holiday season (a potentially important market).

However, if fall production is not a primary objective and instead, early and robust spring yields are desired, we found that the first four fall transplant dates resulted in the same spring yield. Therefore, waiting to transplant into the tunnel until mid-October should not negatively impact spring yields. Additionally, even the latest planting dates (30 Oct and 9 Nov) produced good spring yields, and harvesters noted plants from these later transplant dates had higher quality leaves and a more desirable plant type for harvesting (less bushy) during March and April than spinach transplanted at earlier dates in the fall. **Figure 5** depicts the difference in spring production among fall transplant dates.

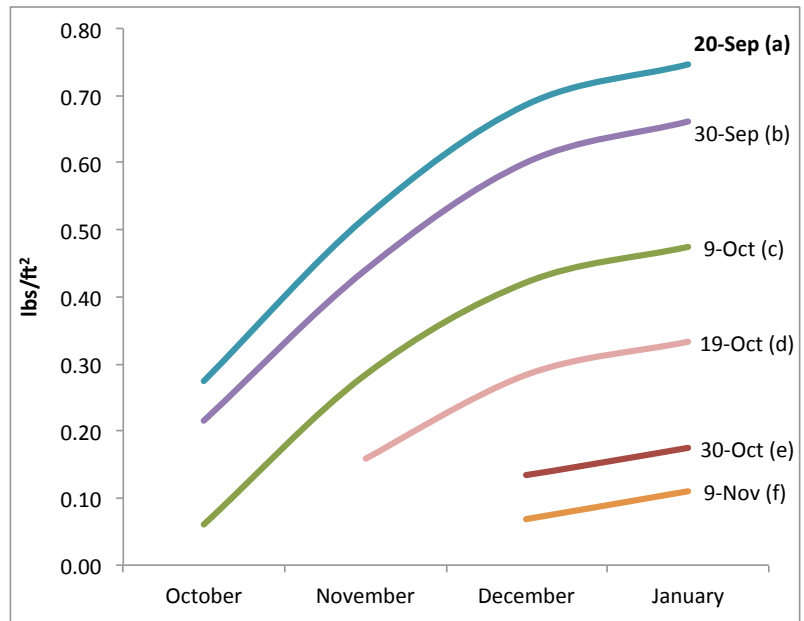


Figure 4. Average total fall & early winter yield (across all varieties). Values sharing the same letter are not significantly different from one another.

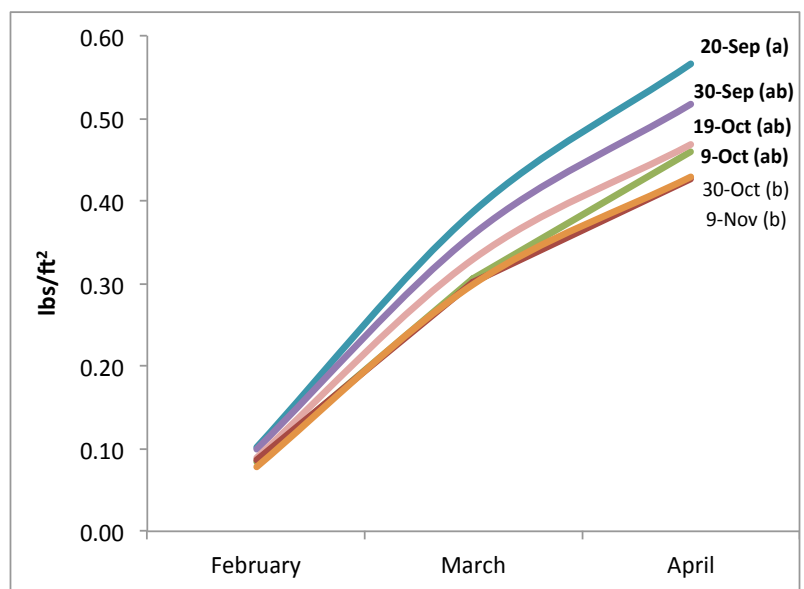


Figure 5. Average total spring yield (across all varieties). Values sharing the same letter are not significantly different from one another.



RESULTS: Variety Selection

During both years of the experiment, Regiment and Space performed similarly in terms of yield and produced significantly higher total yields than Tyee when all six transplant dates were considered. See **Figure 6**. Tyee also exhibited other undesirable characteristics in our trials, such as excessive leaf curling and brittleness. See Figure 3 for an approximate total yield for each planting date.

Cumulative yields from Carmel, Corvair, Emperor, Gazelle, and Renegade are available for a single transplant date, 9 Oct. In both years, we observed no difference in yield between these cultivars. They did, however, exhibit differences in leaf color, shape and size, and plant type/growth habit. **Figure 7** shows production by month for these cultivars. While there were no differences in total yield, Corvair and Renegade produced higher yields than other varieties during the coldest months: January and especially February. Qualitative notes identified Corvair as a “favorite” during winter months for its attractive leaves and growth habit. Additionally, Corvair was the only variety to increase in leaf mass after the winter months.

Variety	2014-15	2015-16
Regiment	ab	a
Space	a	ab
Tyee	b	b

Figure 6. Yield performance of three primary varieties. Values sharing the same letter are not significantly different from one another, ‘a’ is the highest yielding.

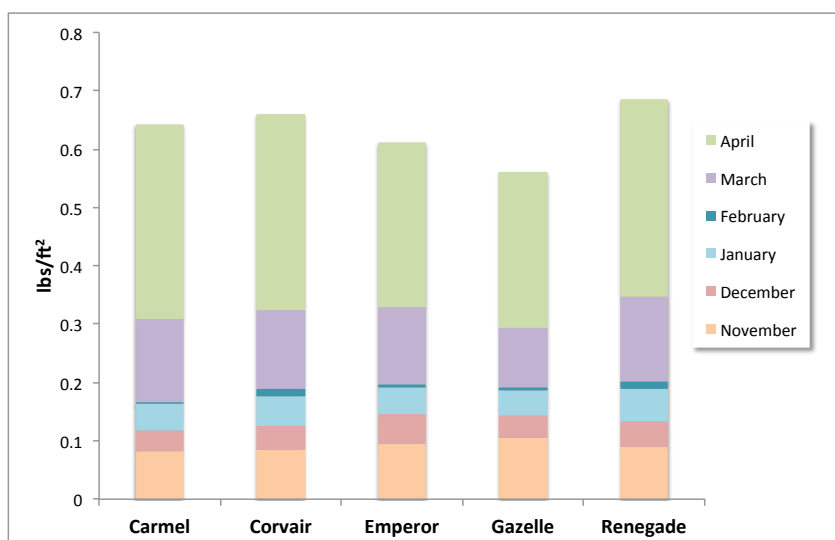


Figure 7. Monthly yields of each variety during the 2015-16 winter season. Values sharing the same letter are not significantly different from each other.

RESULTS: Sugar Content (°Brix)

The sugar content in fruits and vegetables is often correlated with taste and eating quality, with higher sugar levels being more favorable to consumers. °Brix is a measure of the grams of soluble solids, primarily sucrose (table sugar), in a solution - in this case, the liquid extracted from spinach leaves. Other soluble solids such as antioxidants are also heightened under stressful conditions, such as cold temperatures, and are beneficial to human health.



We measured the sugar content of each spinach variety following harvest to determine if differences in sweetness existed among cultivars, and how air temperature within the high tunnel at our location affected these measurements. We observed two trends:

- 1) The high tunnel air **temperature** in the days/weeks leading up to harvest impacted soluble solid content within the spinach leaves
- 2) **Variety** has an influence on sugar content

Temperature

In both years we recorded a direct relationship between temperature and °Brix measurements, with colder temperatures in the days leading up to harvest heightening the sugar content in the leaves. As depicted in **Figure 8**, the lowest sugar measurements were recorded during the warmest periods of the experiment (Oct, Nov, March, and April), and the highest measurements were recorded during the coldest months, February in particular.

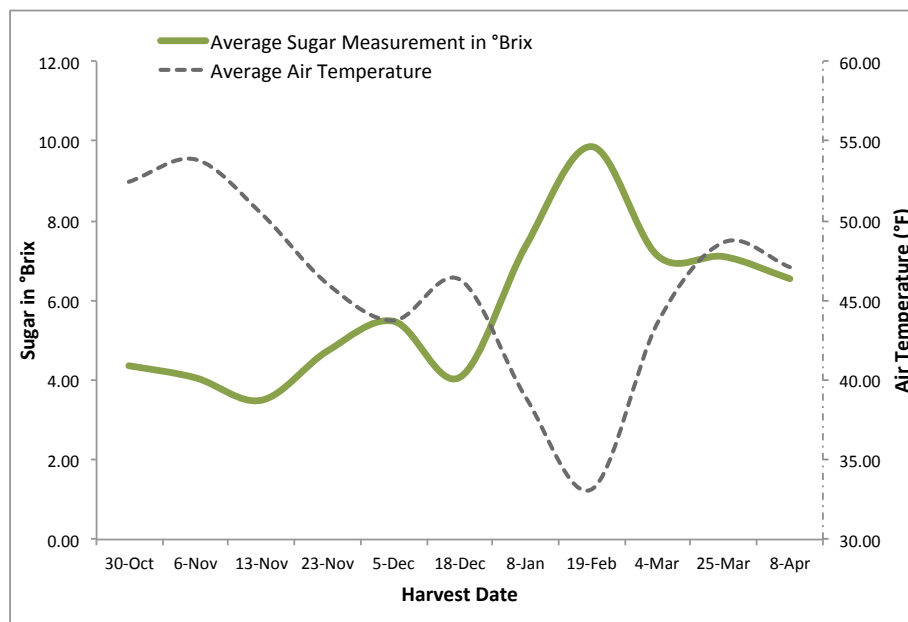


Figure 8. Average air temperatures and °Brix measurements during the 2015-16 experiment. °Brix values are averaged across all eight varieties and were calculated using only the third planting date. Average temperatures were calculated using the days between harvests or the two weeks prior to harvest, whichever was longer, and excluded harvest days.

Variety

Variety also had a significant impact on average °Brix levels, with Gazelle and Emperor having higher average sugar content than other varieties during both years. Despite this statistically significant difference in sugar content among varieties, the range of difference in °Brix isn't enormous, and we felt all varieties were of a high eating quality. We did not conduct raw taste tests of each variety.

Average °Brix
across all sampling dates

Variety	2014-15		2015-16	
Gazelle	11.1	a	6.35	a
Emperor	9.56	b	6.29	a
Space	9.21	c	6.03	b
Carmel	9.08	cd	6.00	b
Corvair	8.94	d	5.60	c
Renegade	8.70	e	5.25	d
Regiment	8.46	f	5.54	c
Tyee	8.24	g	5.63	c

Figure 9. Average °Brix readings for each variety during both years of the experiment. Values sharing the same letter are not significantly different from one another.



Tips & Takeaways for winter & early spring production of spinach in unheated high tunnels.

Transplant Date

- Transplant seedlings in September if the holiday season is a target market. September plantings will also result in the highest total yield through spring.
- If only spring production is of concern, transplanting any date from mid-September through mid-October will result in similar spring yields. Transplanting mid-October through early November also results in good spring yields (but will not produce much prior to spring).

Moisture

Maintaining adequate soil moisture throughout the entire winter season is necessary in preventing plant loss and ensuring growth during these months. Don't be tricked by the snow outside, keep checking moisture levels and irrigate when needed.

Pest Management

Ladybeetles were effective in combatting our aphid population in 2015-16, but at least two harvests were not marketable during the infestation. Using ladybeetles preventatively or another aphid control strategy may be necessary if you experience high aphid populations.

Variety

See below, and the 'Spinach Varieties' sheet for pictures and detailed information.

October	November	December	January	February	March	April
Regiment	Regiment Space Tyee Carmel Corvair Emperor Gazelle Renegade	Regiment Space Renegade	Regiment Renegade Emperor	Regiment Renegade	Regiment Space Tyee Carmel Corvair Emperor Gazelle Renegade	Regiment
Tyee		Carmel Corvair Emperor	Space Corvair	Space Corvair Emperor Gazelle		Carmel Corvair Emperor Gazelle Renegade
Space		Tyee Gazelle	Tyee Gazelle Carmel	Tyee Carmel		Space Tyee

Figure 10. The table above shows how varieties performed during specific months. Those in green boxes produced higher yields than those in red for the month specified. Varieties in grey were neither higher nor lower yielding than those in green or red. These rankings are based on our 2015-16 results.

For more info or with questions, please contact Kaitlyn Orde (kmr28@wildcats.unh.edu) or Becky Sideman (becky.sideman@unh.edu; 603-862-3203).

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Regiment

Lightly-savoyed leaf

Slightly upright growth habit

DMR races 1-7*

- Arrowhead shaped
- Nice light texture to leaf



Space

Smooth to lightly-savoyed

Slightly upright growth habit

DMR races 1-3, 5, 6, 8, 11, 12

- Late Oct & Nov transplants produced very high quality leaves the following spring that plants that tended not to be overly bushy



Tye

Very-savoy leaf

Slightly upright growth habit

DMR races 1-3

- Tendency to exhibit excessive leaf curling and have brittle leaves



Carmel

Slightly-savoyed leaf

Very upright growth habit

DMR races 1-11,13

- Lovely smaller leaves, ideal for fresh eating / baby production
- Very bushy plant
- Time consuming to harvest



Corvair

Smooth leaf

Slightly upright growth habit

DMR races 1-11 (possibly 13)

- Very attractive leaves,
- Favorite during Mar & Apr for consistent size and good quality
- Quick to harvest



Emperor

Semi-savoyed

Very upright plant

DMR races 1-10

- Nice light texture to leaf



Gazelle

Smooth leaf

Very upright growth habit

DMR races 1-13

- Dark shiny leaves
- Increased in bushiness over winter season
- Tendency to slightly yellow on the edges



Renegade

Smooth leaf

Oblate growth habit

DMR races 1-7

- Rounded leaf apex
- Nice but strong texture
- Quick to harvest



Upright growth habit of Emperor (L) next to the more oblate Renegade (R).



*DMR = Downy Mildew Resistance. Resistance info obtained from seed sources.